Technical Note DOER-C5
September 1999

Bioremediation of PAH-Contaminated Dredged Material at the Jones Island CDF: Materials, Equipment, and Initial Operations

PURPOSE: The U.S. Army Engineer District, Detroit, is currently conducting a bioremediation demonstration project at the Jones Island confined disposal facility (CDF), Milwaukee, WI. Dredged material contaminated with polycyclic aromatic hydrocarbons (PAHs) is being bioremediated using composting technology. This technical note describes the materials, equipment, and initial operations at the Jones Island CDF bioremediation project. The purpose of the Jones Island bioremediation project is to test the feasibility of using low-cost and relatively passive biotechnology to reduce PAH concentrations and convert the dredged sediment to material suitable for offsite beneficial uses.

BACKGROUND: Shipping channels and harbors in the United States require periodic dredging to maintain depths for commercial navigation. Under current policy guidance contained in "National Harbors Program: Dredged Material Management Plan" (21 July 1994), the Corps is developing management plans to address how dredged material at all harbor projects will be handled over the next 10 years. Under this program, the Detroit District initiated development of a Dredged Material Management Plan (DMMP) for the Port of Milwaukee. Initial proposals considered the construction of a new CDF at a projected cost of $13M. The Port of Milwaukee requested that the District consider other alternatives in the DMMP, such as reduction of dredging quantities and beneficial use of dredged material.

Although Corps policy directs that dredged material management planning should consider opportunities for beneficial use, the alternatives for contaminated dredged material have been extremely limited. Traditionally, the most cost-effective alternatives for management of dredged material unsuitable for unrestricted open-water disposal or beneficial use have been capping and disposal in CDFs - diked structures designed to retain solids. Many Great Lakes CDFs are now nearing or exceeding design capacity. Of the 26 Federally funded CDFs built in the Great Lakes under PL 91-611, all but two are scheduled to be filled by the Year 2006 (U.S. General Accounting Office 1992).

One criticism of CDFs is that they are not designed nor managed to treat the pollutants placed inside. Therefore, construction and management of CDFs must consider that they be maintained in perpetuity, and the adequacy of engineering controls at CDFs is sometimes a source of concern among Federal and State regulatory agencies, environmental groups, and the public. There is a need, therefore, to advance CDF technology beyond storage and containment.

Many CDFs were constructed in-water or nearshore, and water captured during construction was not removed. Initial placement of dredged material was directly into standing water. Most in situ sediments are anaerobic, and dredged material placed below the saturated zone remains in the original highly reducing conditions. As CDFs reach design capacity, material emerges from the water, and aerobic conditions develop in the surface layer as the material dewaters by evaporation.

In the Great Lakes, vegetation quickly covers the exposed dredged material, and the resulting evapotranspiration assists dewatering.

CDF closure studies conducted by the Detroit District have shown that organic contaminant concentrations in CDFs tend to be reduced in the upper unsaturated zone, whereas contaminant concentrations remain unchanged in the saturated zone. For example, PAH analysis of samples from six borings in the Milwaukee CDF shows that the upper layers are less contaminated than the lower layers (Figure 1). Although variations in contamination levels in the dredged material disposed over two decades could account for the profiles shown in Figure 1, the fact that the most recently dredged material has been placed in the open-water area of the CDF (Figure 2) suggests that this is not the case. The profiles are more consistent with the top-down, self-cleaning hypothesis (Myers 1996) involving intrinsic biodegradation and clearly show that the top meter of material is substantially cleaner than the material lower down in the CDF. Similar contaminant levels with depth profiles have been observed at the Renard Island CDF in Green Bay, WI.

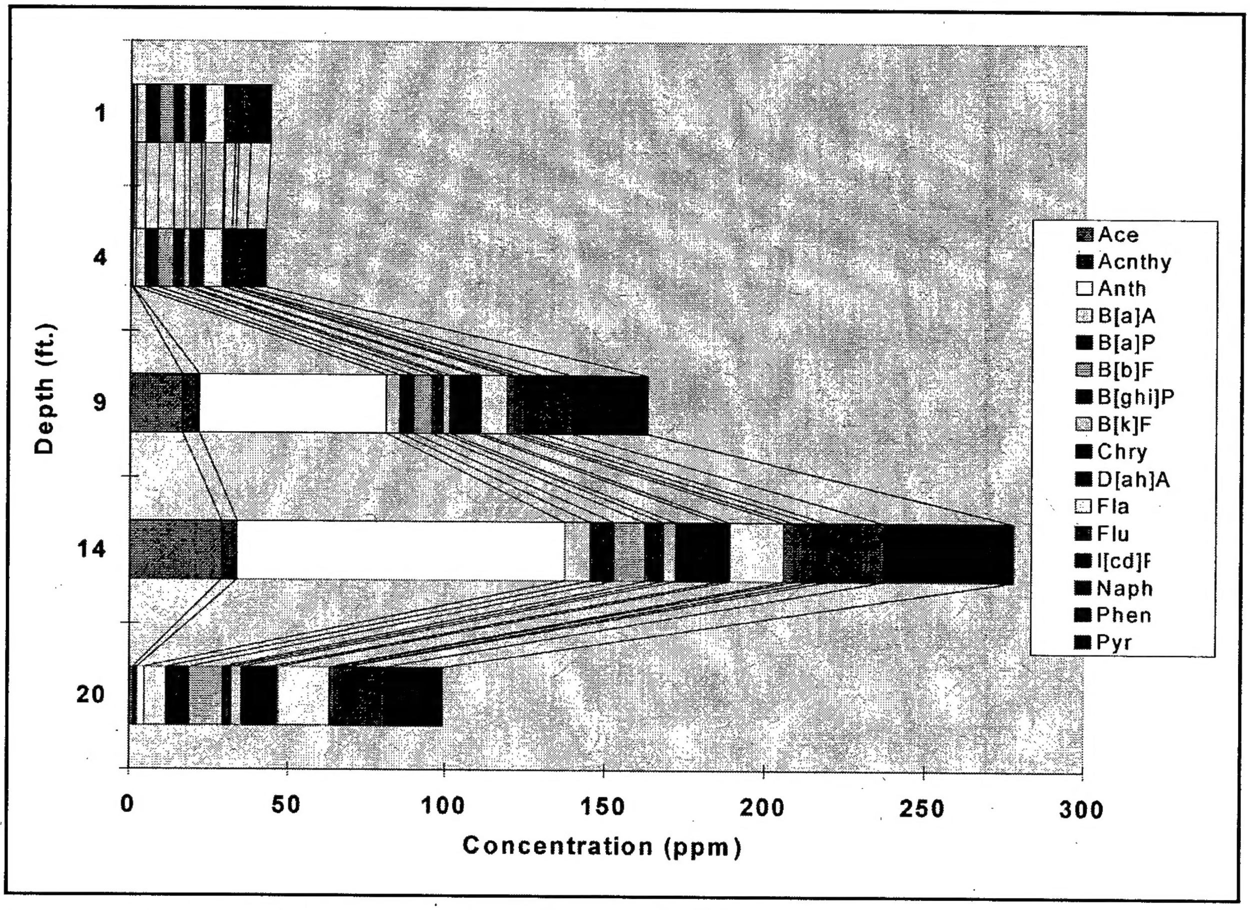

Figure 1. PAH concentrations with depth at Milwaukee CDF, Milwaukee, WI

PAHs appear to be biodegradable compounds (Herbes and Schwall 1978; Cerniglia 1984; Bauer and Capone 1985; Mihelcic and Luthy 1988; Lewis 1993; Jones, Araujo, and Rogers 1996), but only under optimal conditions. Typically, the sediment or soil must have an abundant supply of oxygen, nutrients, and moisture. Fortunately, polluted dredged material is typically high in macro

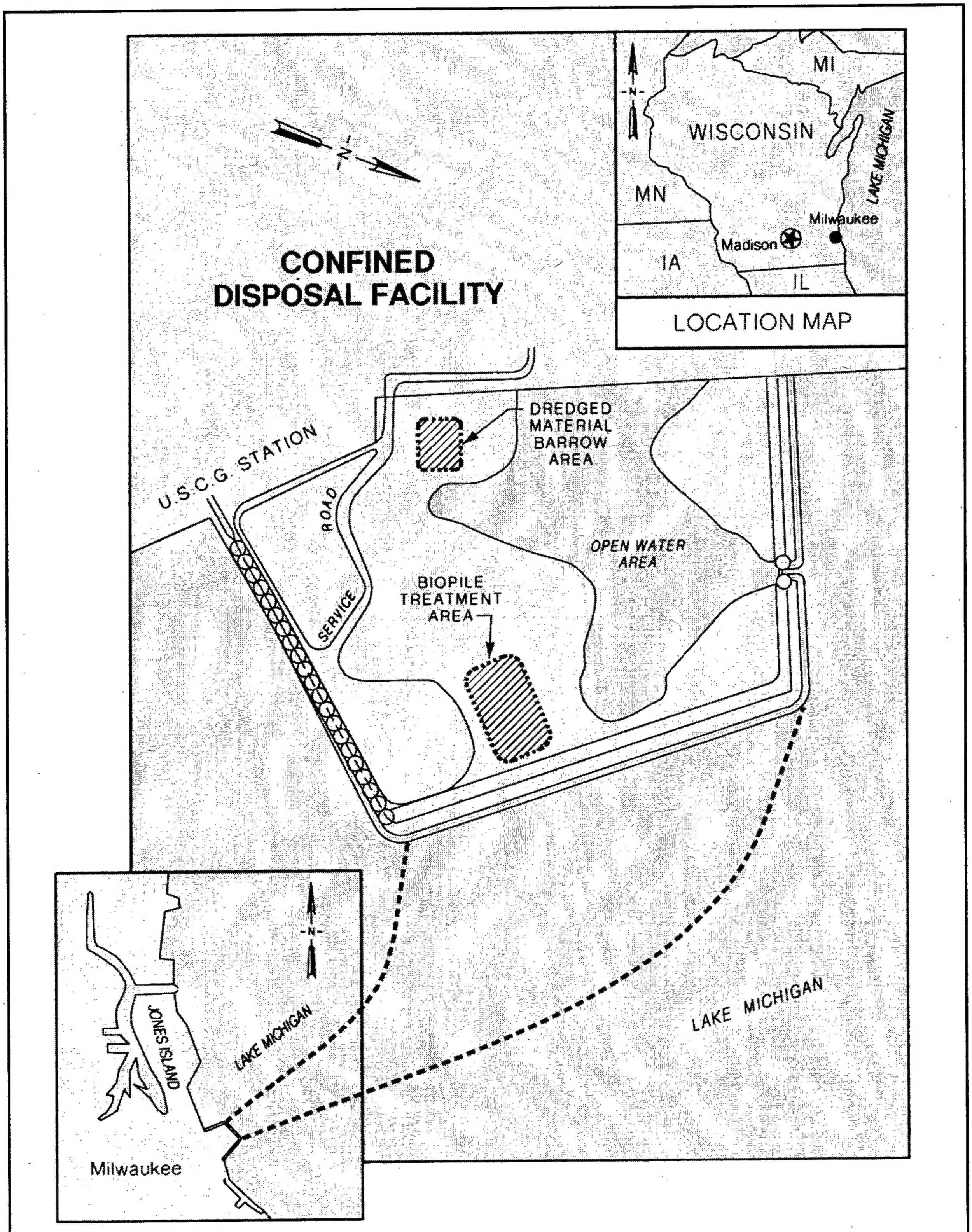

Figure 2. Vicinity map for the Jones Island CDF

and trace nutrients, and water is usually available on or near by CDFs. Keeping oxygen in abundant supply, however, is a problem in dredged material because of the high biochemical oxygen demand of the material and the slowness of diffusive oxygen transfer. Oxygen transfer can be enhanced by the creation of biomounds (mounds or windrows of contaminated soil or sediment, mixed with a bulking agent such as wood chips and often a biosolid, such as sewage sludge). Biomound composting technology has been successfully used in Minnesota to treat petroleum-contaminated soil for several years (Kamnikar 1996). Biomound-type composting is relatively inexpensive compared with bioslurry, bioventing, and temperature-controlled composting technologies. There is a potential, therefore, to cost-effectively enhance intrinsic bioremediation processes in dredged material by improving oxygen transfer from the atmosphere using biomound composting technology.

SITE DESCRIPTION: The 44-acre Jones Island CDF at Milwaukee, WI, was constructed in 1975 and is located in the south outer harbor (Figure 2). The CDF serves as a disposal facility for maintenance dredged material that is unsuitable for open-lake disposal from both Milwaukee Harbor and Port Washington Harbor, located 25 miles north of Milwaukee. The design capacity of the Jones Island CDF is 1.2 million cubic meters (MCM) (1.6 million cubic yards, MCY). Until recently, annual maintenance dredging quantities typically ranged from 38,000 to 73,000 CM (50,000 to 95,000 CY). Completion of a storm-water interceptor system in Milwaukee in 1994 reduced annual dredged quantities to around 19,000 CM (25,000 CY). The remaining capacity is 325,000 CM (425,000 CY), and it is expected that the CDF will be filled in 20 years.

PROJECT OBJECTIVES: The short-term objectives for the Jones Island bioremediation project are to reduce PAH concentrations to levels that will allow offsite beneficial use at the lowest costs. The long-term objectives involve developing a cost-effective treatment train for handling and managing dredged material and eventually creating a marketable product. Supporting objectives for the Jones Island demonstration project are as follows:

- Obtain cost and performance data to assist the Corps in developing management options for contaminated dredged material.
- Provide data of sufficient quality to make a determination with regard to offsite beneficial use options for dredged material in the Jones Island CDF.
- Test and evaluate an innovative piece of equipment for turning and aerating dredged material.

Table 1 lists PAH concentrations in surface material from the Jones Island CDF and State of Wisconsin criteria for reuse. A specific objective of this project is to reduce the concentrations of benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno-(1,2,3-cd)pyrene to meet Wisconsin's standards for beneficial use of industrial byproducts.

MATERIALS AND EQUIPMENT: Wood chips were provided by the Port of Milwaukee in coordination with the City of Milwaukee right-of-way maintenance program. Wood chips facilitate aerobic biodegradation of pollutants in the following ways:

- Contain white rot fungi (very good at degrading complex organic compounds).

Table 1
PAH Concentrations (mg/kg) in Surface Material at the Jones Island CDF

Compound	Concen-tration*	NR 538** Category 1	Exceeds	NR 538** Category 2	Exceeds
Acenaphtene	0.203	900		9000	
Acenaphthylene	0.203	8.8		88	
Anthracene	0.234	5000		50000	
Benzo (a) anthracene	0.672	0.088	X	0.88	
Benzo (a) pyrene	0.666	0.0088	X	0.08	X
Benzo (b) fluoranthene	0.609	0.088	X	0.88	
Benzo (g,h,I) perylene	0.534	0.88		8.8	
Benzo (k) fluoranthene	0.614	0.88		8.8	
Chrysene	0.777	8.8		88	
Dibenzo (a,h) anthracene	0.243	0.0088	X	0.088	X
Fluoranthene	1.405	600		6000	
Fluorene	0.206	600		6000	
Indeno (1,2,3-cd) pyrene	0.458	0.088	X	0.88	
Naphthalene	0.209	600		6000	
Phenanthrene	0.824	0.88		8.8	
Pyrene	1.374	500		5000	

* Mean of 12 samples.
** State of Wisconsin regulation for use of solid waste as fill material, Category 1 - unrestricted, Category 2 - restricted to transportation facility embankment (capped), surface course (roadfill), and unconfined geotechnical fill (not residential).

- Hold moisture.
- Provide a pad for construction equipment.
- Create air pockets within the mound.
- Allow convective transport of oxygen into the mound from below.
- Add a coarse fraction to the dredged material, making it easier to handle.

An innovative piece of equipment called the SCAT® 481Turner (SCAT Engineering, a Division of ATI, Inc., Delhi, IA) is being used at the Jones Island CDF bioremediation project to mix wood chips with dredged material. The SCAT® 481 Turner (Photo 1) is designed to mix and aerate compost windrows. The turning unit is pulled by a Cat D4C tracked dozer or similar equipment. The operator can adjust the angle of bite and turner speed from the dozer using hydraulic and electronic controls. The turner consists of a chain-driven metal belt outfitted with metal teeth. The chain drive is powered by a 40 HP diesel engine on the turner unit. As the spinning belt is pulled into a windrow, material grabbed by the teeth moves up the belt and is thrown over the top of the belt. This action blends and aerates material.

PROGRESS TO DATE: During the summer of 1997, a treatment area (152 by 30 m) was cleared and leveled on the Jones Island CDF. Before the construction season ended in the fall, dredged

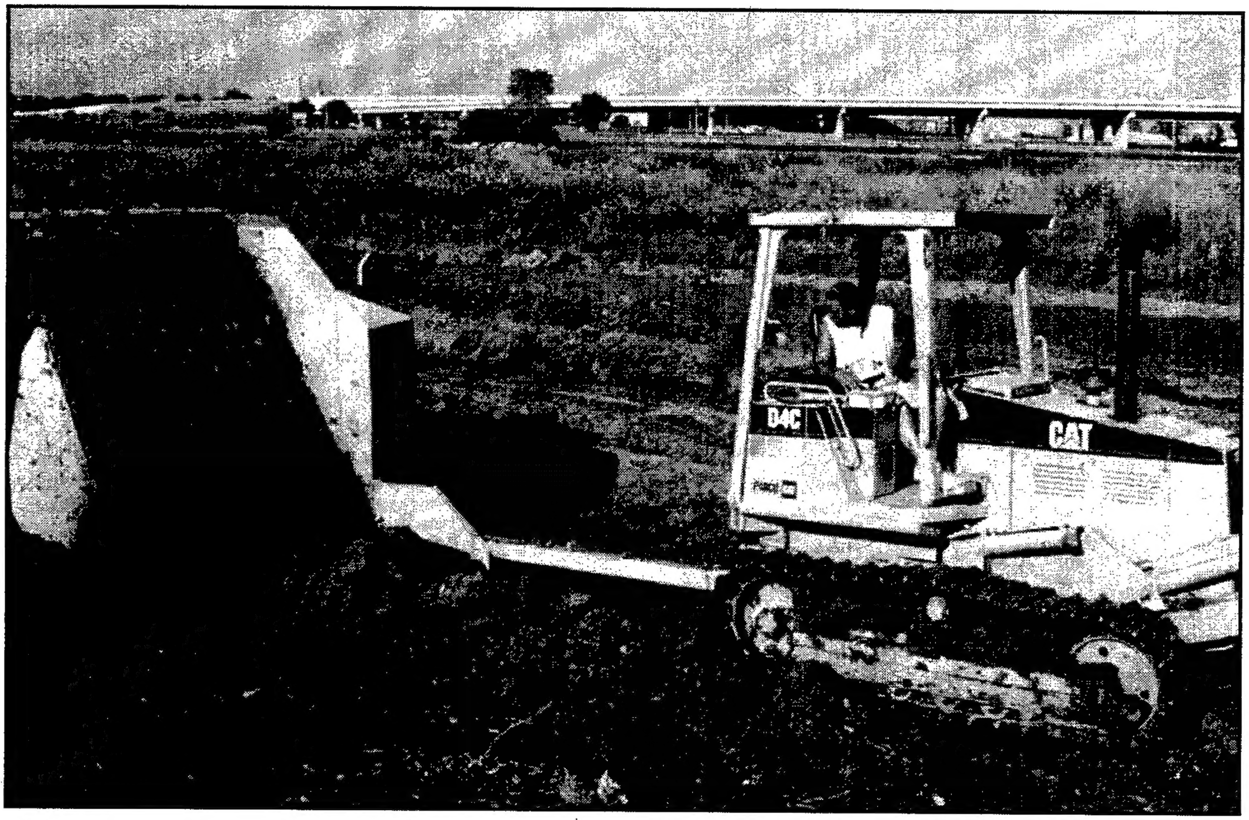

Photo 1. SCAT® 481 Turner at Milwaukee CDF, 8/98

material from the surface of the CDF was excavated and moved to the treatment area on the CDF. A mat of wood chips (25 cm thick) was laid down over the treatment area. Additional wood chips were placed in the windrow locations to provide a dredged material:wood chip ratio of 4:1 (vol:vol). Dredged material was then placed on top of the wood chips in the windrow locations and mixed with the wood chips using the SCAT® 481 Turner. Figures 3 and 4 show windrow cross sections before and after mixing. The windrows are 150 m long.

Windrows were constructed during the late fall of 1997, but the turning operation could not be initiated until the third week of July of 1998 because the turner was not available until then. The thick vegetative cover that developed during the spring of 1998 demonstrated the potential of this material for growing plants. The SCAT® Turner 481 had no difficulty with turning this vegetation into the dredged material/wood chip mix (Photo 2). Additional wood chips were mixed into the windrows using the SCAT® 481 Turner, and thereafter, the SCAT® 481 Turner was used to turn the dredged material/wood chip mix on a weekly basis. Within a month, the weekly mixing cleared the windrows of plants. Debris such as tires and small stones (5-cm diam and 20-cm length) were no problem for the SCAT® 481 Turner. Items such as these are picked up by the turner; as they bounce on the belt, they work themselves to the side where they fall off. Heavier debris that the turner could not pick up, such as large chunks of concrete, had to be removed either manually or with a front-end loader. The SCAT® Turner takes about 30 min to make two passes on each windrow for a total work time of about 2 hr. (The turner leases for $5,000.00 per month.) At the end of turning, the windrows were well mixed and well aerated.

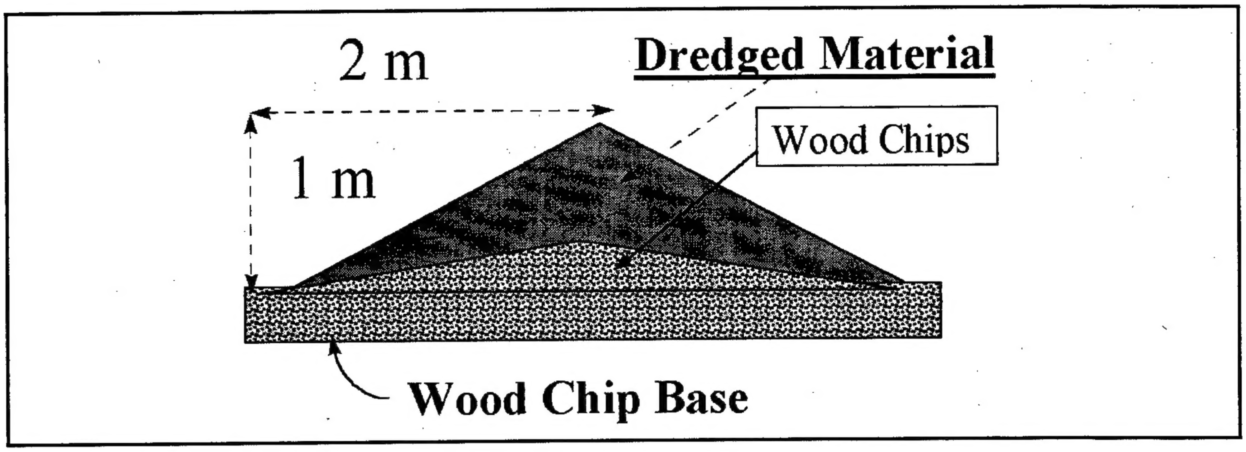

Figure 3. Schematic of windrow cross section before mixing

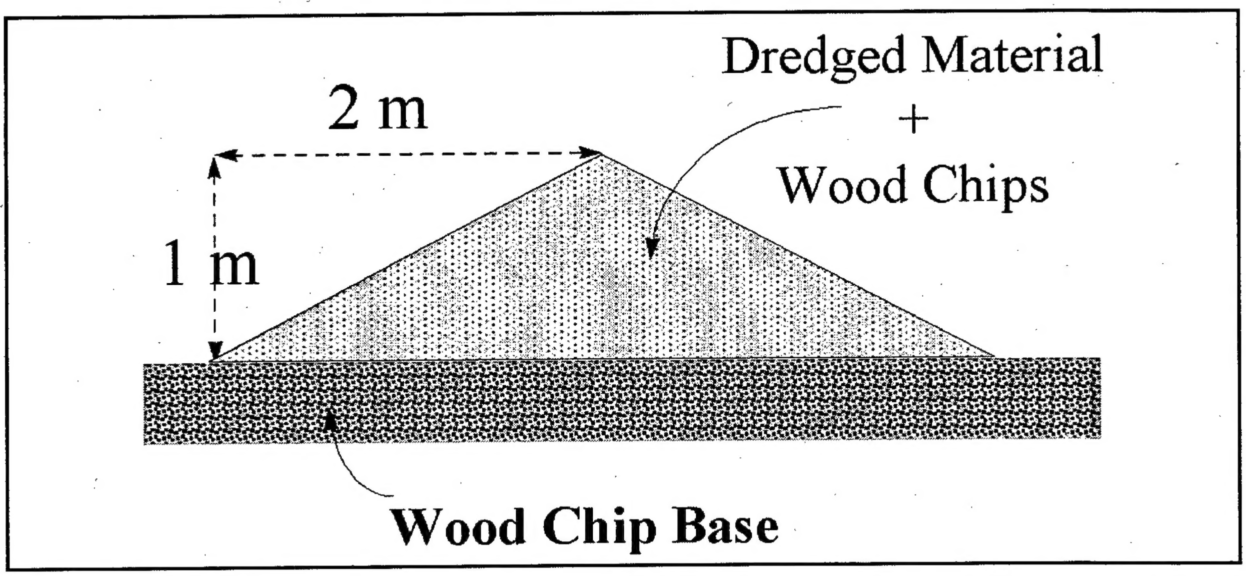

Figure 4. Schematic of windrow cross section after mixing

Measurements of oxygen and carbon dioxide concentration, temperature, pH, and moisture content are collected each week before turning. Concentrations of PAHs, nitrogen, phosphorus, and other parameters are collected at the end of each month. On the basis of these results, water and/or nutrient additions are made. Target ranges for selected parameters are listed in Table 2.

Table 2
Monitoring Parameters for Biomounds at the Milwaukee CDF

Parameter	Minimum	Maximum	Monitoring Frequency
Oxygen	2%		Weekly
Moisture	40%	80%	Weekly
C:N:P*	100:1:0.5	100:10:1	Monthly
pH	6.0	8.0	Weekly

* C:N:P = carbon:nitrogen:phosphorus ratio.

Photo 2. SCAT® Turner at Jones Island CDF, 7/98

At the time this technical note was prepared, minimal monitoring data were available. No PAH data were available. The data available through mid-August 1998 showed some oxygen utilization. Oxygen concentrations were down from 20 percent to about 15 percent in the biomounds. Maintaining moisture in the mounds within the target range has been difficult. Initially, the mounds were at low moisture (<10 percent) in July 1998. During the second week of the study, water was pumped onto the mounds to increase moisture content. This was easily accomplished by drawing water from the open-water area in the CDF. A few days later, a storm dumped several inches of rain on the CDF. Despite these soakings, the moisture content within the mounds rose only to about 20-30 percent. Moisture may prove to be a critical factor in management of the biomounds because biodegradation is expected to be considerably reduced below a moisture of 40 percent and turning operations are hindered when moisture rises above 50 percent.

FUTURE PLANS: The current project has been continued in Fiscal Year (FY) 99 with significant additions to the demonstration project. Dredged material and wood chips will be mixed with caked biosolids from a nearby municipal wastewater treatment plant. The benefits of blending other materials such as lime and flyash to immobilize metals will also be investigated. Greenhouse studies of plant uptake and equipment for the removal of wood chips and other debris that may be required to make the material marketable will be evaluated. Partners in the FY99 effort include the U.S. Environmental Protection Agency Great Lakes National Program Office in Chicago, IL, the Port of Milwaukee, and United Water Services (contractor to the City of Milwaukee for operation of wastewater treatment plants).

SUMMARY: Construction and operation of biomounds on CDFs as the first step in a dredged material management plan appear to be a feasible alternative. The SCAT® 481 Turner seems to provide good aeration and mixing of dredged material. The turner was able to thoroughly mix wood chips with dredged material and was able to handle debris without malfunctioning.

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